High-Temperature Instrumentation

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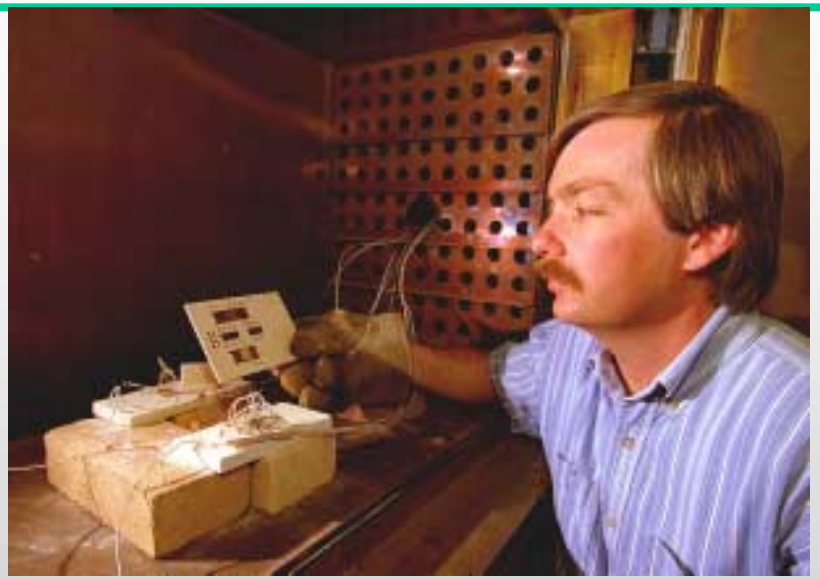
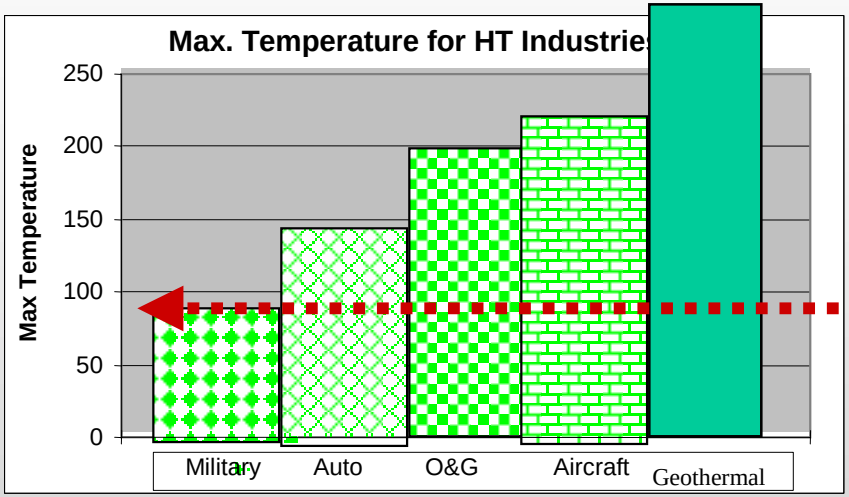
Background

- First to test SOI (Silicon-On-Insulator) electronics to 300C.
- The Honeywell SOI microprocessor shown operated up to 310C continuously reporting to the screen below, “Do you call this hot? Turn up the heat!!”
- A new HT electronic project soon started at Sandia.

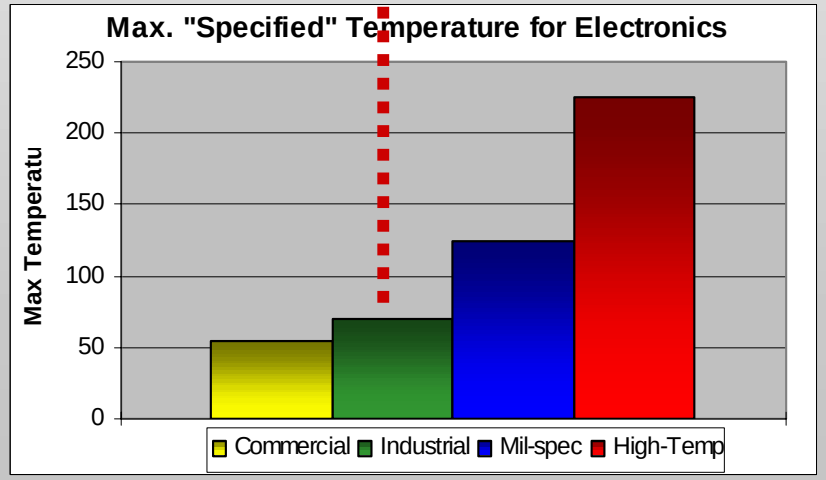


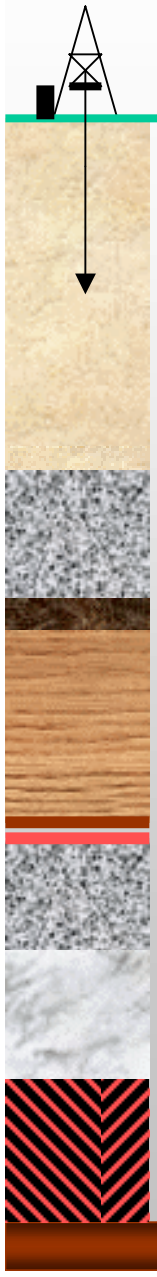
Geothermal Stands at the Top of HT Electronics Needs



The need for high-temperature electronics above the military specification is growing. However, the geothermal market is the only "real market above 225C.

To meet that need a new level of commercially available HT SOI, (Silicon-On-Insulator), is being developed, offering almost twice the military temperature range.



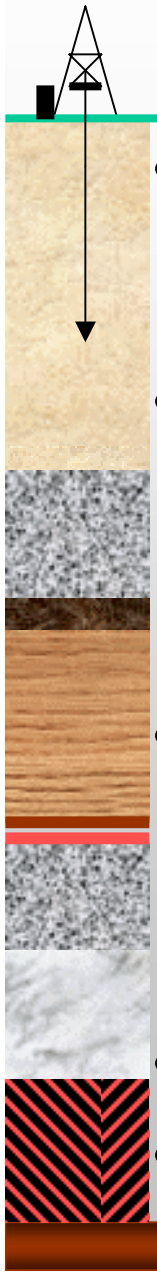


Geothermal Program Objective:

To develop and demonstrate new high temperature, unshielded geothermal logging tools and systems; seeding the geothermal industry with this new technology.

High-temperature means 200 to +300C.

Seeding means to teach others well enough for them to continue development.



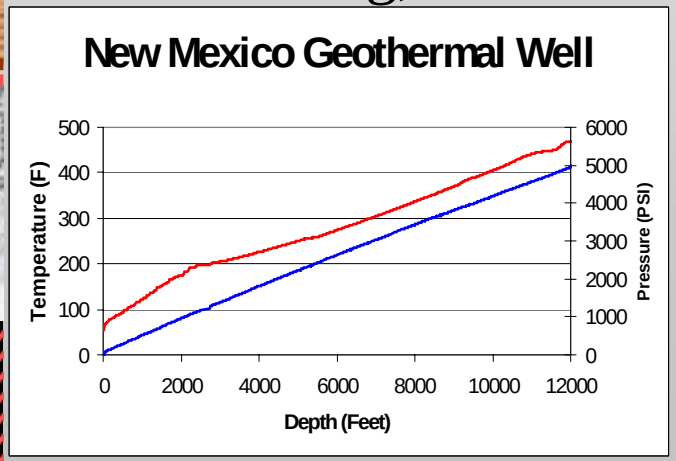
Why Unshielded Electronics?

- To reduce tool cost
  - The Dewar cost is $8-16K, HT electronics cost $5-8K; however these costs will fall as production increases
- To reduce $$$ risk to operators
  - Eliminate or reduce tool loss to heat damage inside the well, higher likelihood of recovering lost tools
  - Wells will NOT require cooling before logging
- With increase time downhole
  - Casing inspection tools work best when run slowly
  - Continuous downhole monitoring for production testing
  - New MWD tools to improve geothermal drilling
- Reduced tool diameters
- Potential for 500-600C well logs

SOI Logging Tool Demonstration

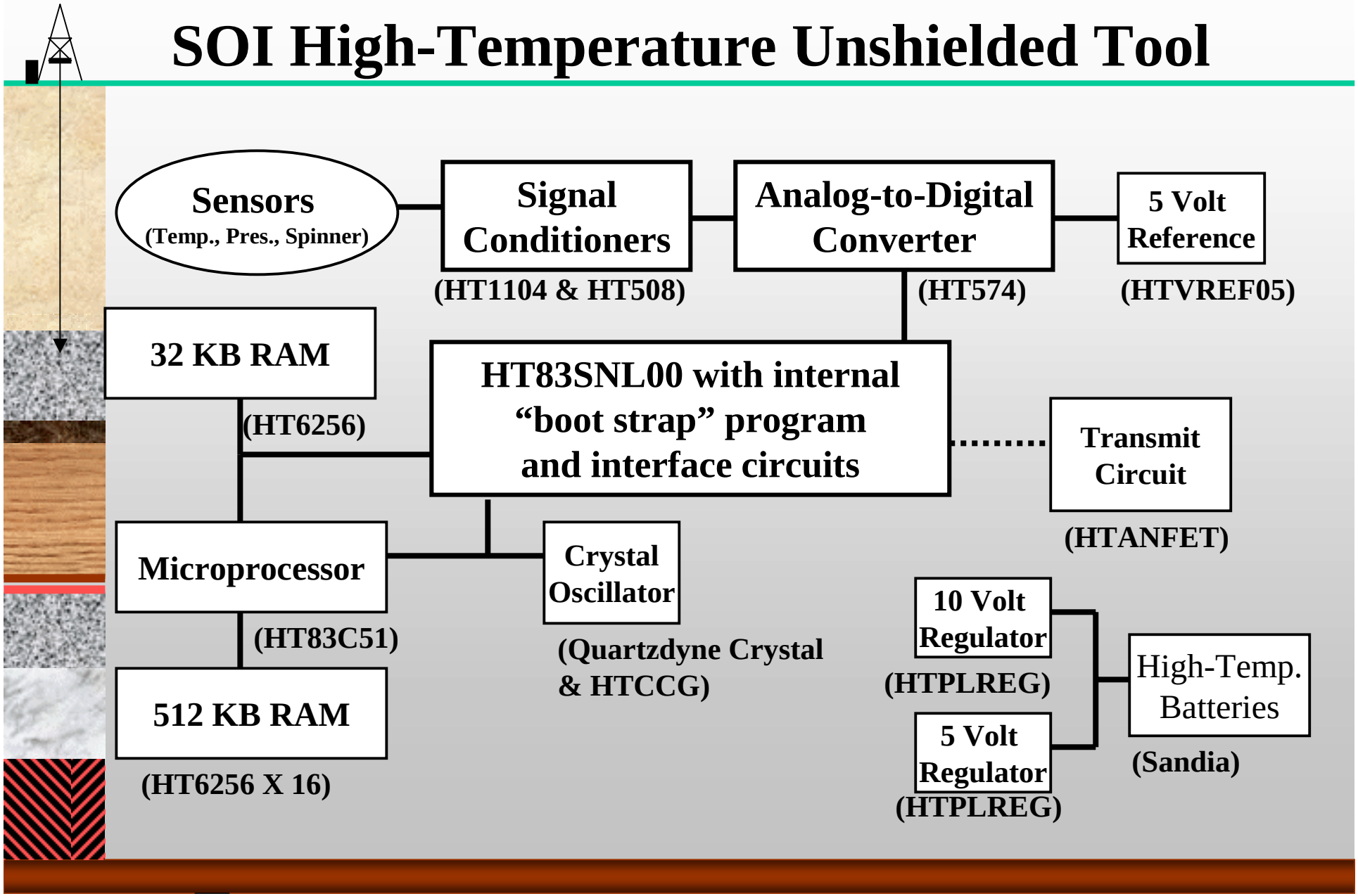
The ASIC

Bearfoot Log, 240C

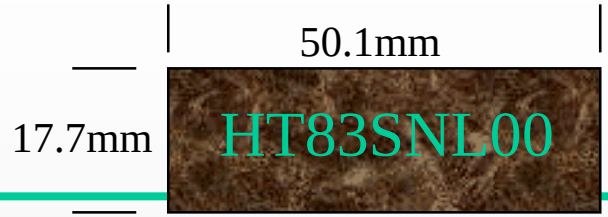


- March 2001, the Sandia designed HT83SNL00 was delivered!
  - It greatly enhances the HT SOI tool capability while reducing tool diameter
- Nov 2001, completed a long term downhole test inside a 240C geothermal well for some 40hrs.
- After well log, the tool was placed within an oven at 225C for ~1000 hrs!!!

SOI High-Temperature Unshielded Tool



Chip set will power up and start logging for easy operation

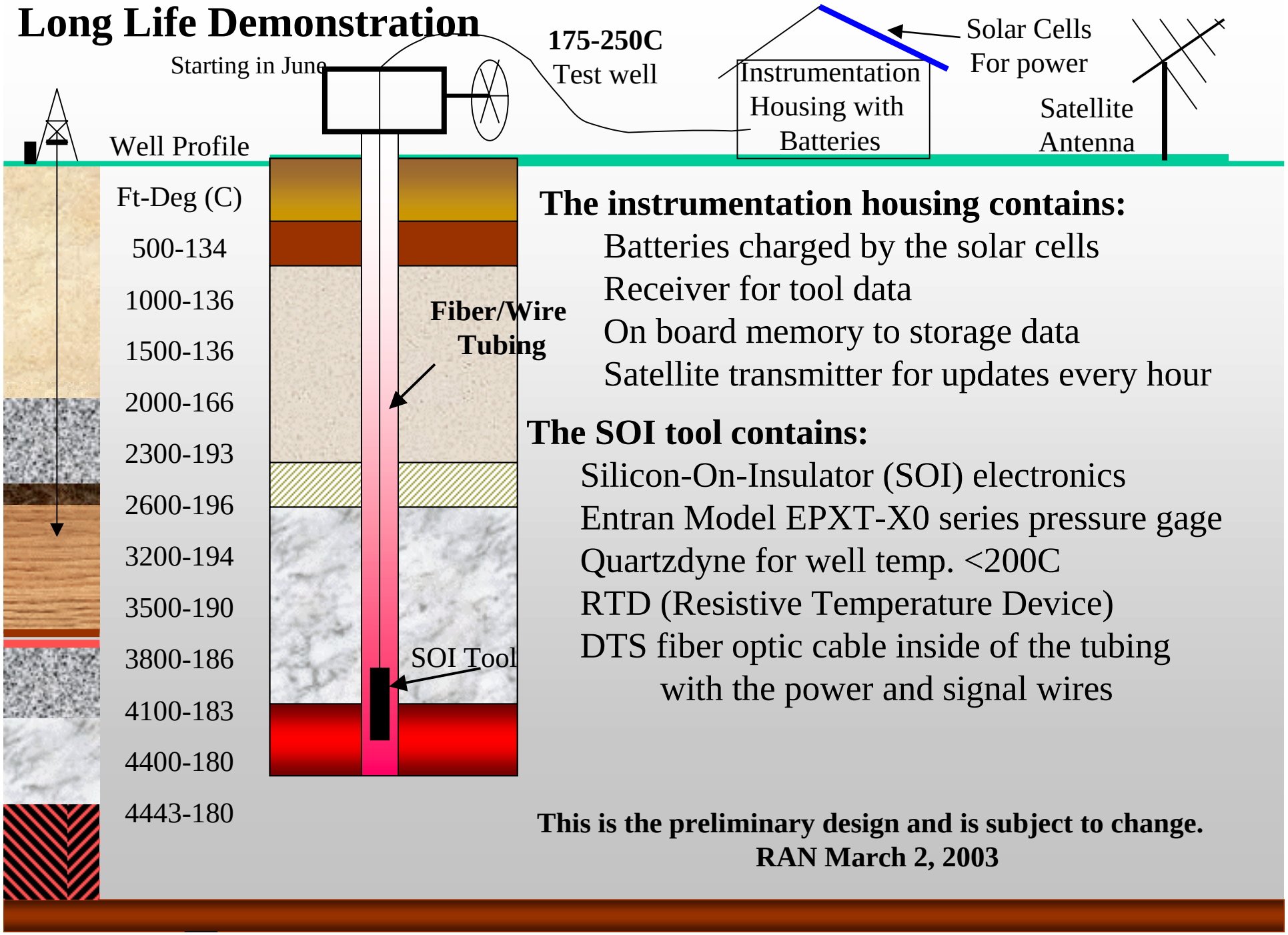


The package will have a 0.7in (17.7
board size down and have a 0 to 30

This chip set can be master/slave configured for doubling the number of data channels!

Long Life Demonstration

Starting in June



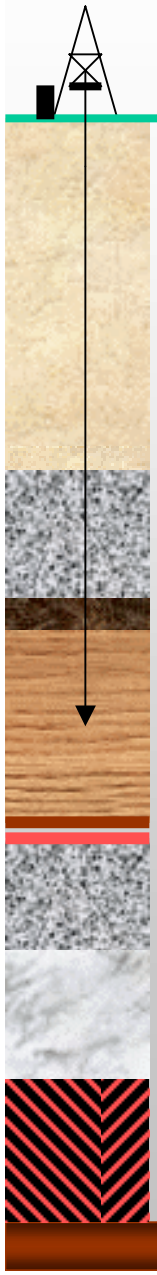
The instrumentation housing contains:

- Batteries charged by the solar cells
- Receiver for tool data
- On board memory to storage data
- Satellite transmitter for updates every hour

The SOI tool contains:

- Silicon-On-Insulator (SOI) electronics
- Entran Model EPXT-X0 series pressure gage
- Quartzdyne for well temp. <200C
- RTD (Resistive Temperature Device)
- DTS fiber optic cable inside of the tubing with the power and signal wires

This is the preliminary design and is subject to change.
RAN March 2, 2003



Developing New Components

- Capacitors
  - Johanson Dielectrics: New dielectric is more stable at 200-300C. Presently building 250, 0.1uF capacitors for life testing at 250C.
  - Sigma Technologies: 1uF and 20uF +200C Polymer capacitor starting production
  - Calramic: Testing a 1uF, 300C ceramic capacitor
  - Novacap: Presently being used in the Sandia SOI tool
  - More work is needed in 10-100uF capacitors at +200C
- Printed Wiring Boards
  - Multilayer: Presently used in Sandia SOI tool
  - NREL: Karen Moore working on new glue less ceramic board for over 300C. Easier to make, can be 12 in diameter and improved thermal conductivity.

Developing New Components

- **Pressure Sensors**
  - Entran: Developing 300C strain bridge type
  - Quartzdyne: Working to improve existing quartz gage to 225C
- **Clock Oscillators**
  - Linear Measurements: Using a new type of crystal for +300C
  - Quartzdyne: Presently makes 250C crystal. Working on a 300C version
- **Solders**
  - Sandia: Paul Vianco
  - A lot of work is needed here

Developing New Components

- **Vibration**
  - Silicon Designs: Nearing completion of first prototype 2 G MEM-SOI vibration and inclination sensor rated for 275C
  - Sandia: Developing an SOI interface for the Endevco 275C piezoelectric vibration sensor line
- **Steering sensor package**
  - Steven Rountree: Developing a steering sensor for 250C.
    - Measures azimuth and inclination for dead reckoning the drilling location
- **Fiber Optics**
  - Fiber Guide: We have ~9000 ft of low phosphorous fiber for testing.
    - 3000 ft of fiber is ready for wellbore deployment at 200-250C

Developing New Components: Batteries

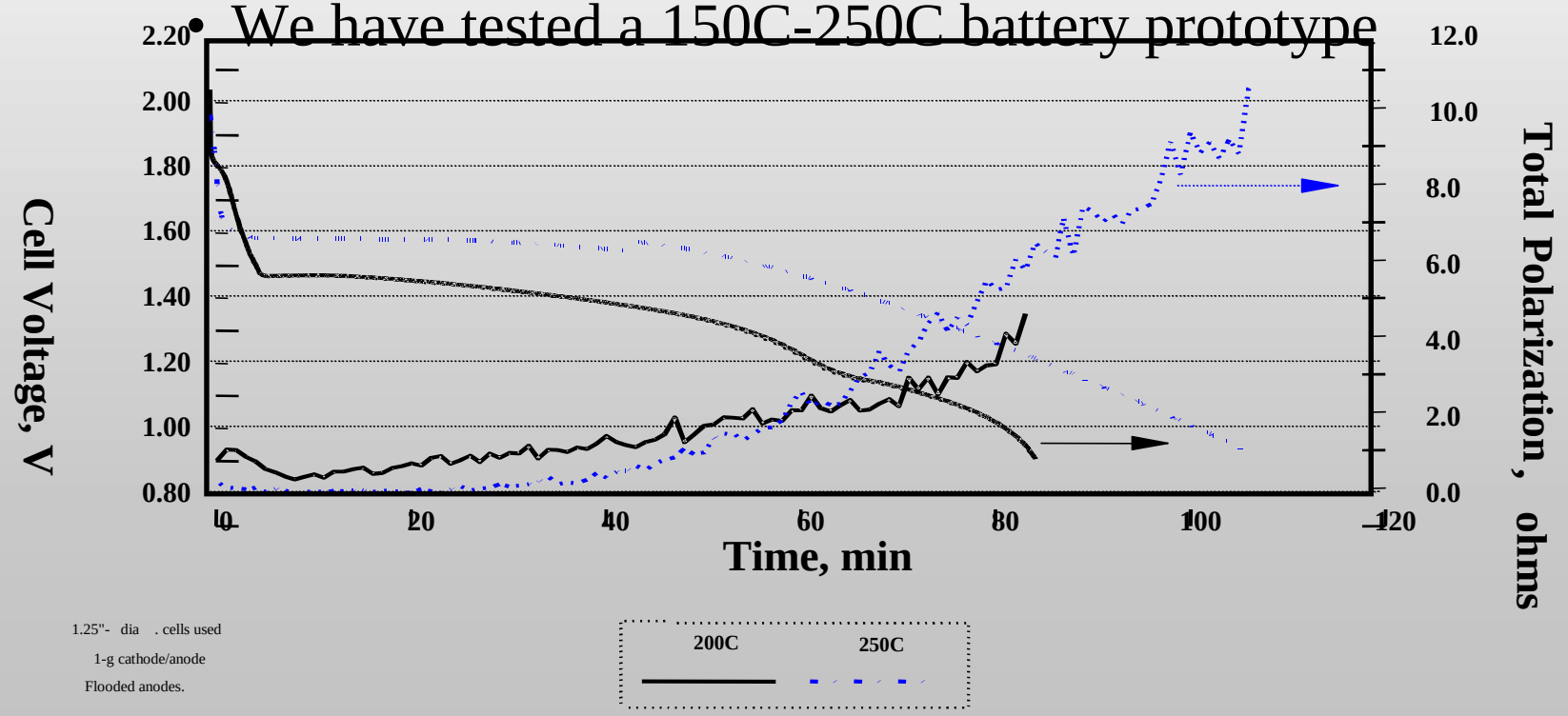
- **Molten Salt**
  - Molten salt batteries require some heat to activate.
  - Some can be recharged (at temp)
  - Have a very long shelf life, military uses
  - Eagle-Picher Ind: Developing a thermal battery for 150-250C. They have the capability of thermal batteries already for 250-500C. (Sandia has a researcher looking at room temperature thermal batteries)
- **Solid State**
  - Very wide operating temperature range, high internal resistance
  - Green
  - General Atomics: Keep-A-Live battery for room temperature to 250C (500C). Presently working to reduce internal resistance. Could be used as primary power.

Thermal Battery Results

- **Rechargeable, Thin, Single Cell Battery**

  (Test Current = 60 ma)

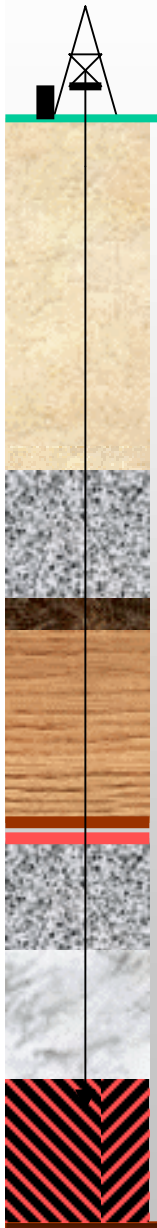
  - We have batteries for 250C and above
  - We have tested a 150C-250C battery prototype



New Tools Improve the HT Component Market

- **P/T tool rated for 250C continuous operation:**
  - E-Spectrum: Working on a Universal Logging Computer for 250C. Presently requires ROM for the SOI HT83C51 processor. They have a working analog 8 channel differential measurement electronics for 250C.
  - PhotoSonic: Developing improvements for the Sandia SOI tool. May include existing flow measurements using HT PhotoSonic 300C optical flow sensor.
  - LEL Corp.: A mechanical fiber optic sensor for temperature and pressure measurements
- **Others**
  - Rockwell International: Using Sandia SOI for 225C motor controller
  - Tecnomare SpA: Using Sandia SOI for Seismic Tool
  - Instituto de Investigaciones Eléctricas: Using Sandia SOI for Gamma Tool

Industry Needs To Keep Improving HT Electronics



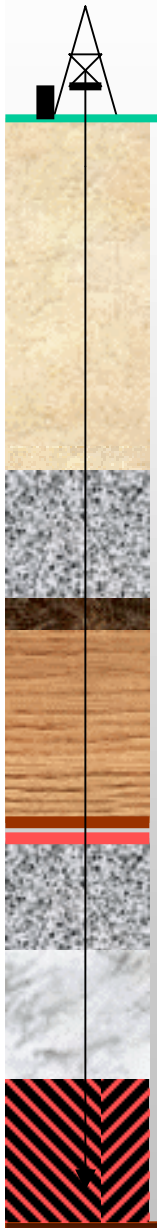
- HT Electronics Standard needs JPL/NASA
- Low drift HT instrumentation amplifier
  - Tons of sensor applications
- Voltage reference
  - Honeywell's SOI Vref is limited to 260C
- EEPROM
  - Fraunhofer Institute has demonstrated an SOI EEPROM for data storage but discontinued the program
- Solder
  - This is a manufacturing problem for HT systems
  - Reduced reliability

Education: Learning Aids

- Technical learning aids are extremely important
  - Giving the industry a low temperature evaluation board

    - » A low temperature version is cheap to build and lets industry develop new tools in-house at very low cost. This way each company can seek a competitive edge by making their tool customized.
    - » Documentation is good but a prototype is worth a 1000 man-hours.
  - Jump start select geothermal service companies with a beta high-temperature versions to get them fully started.

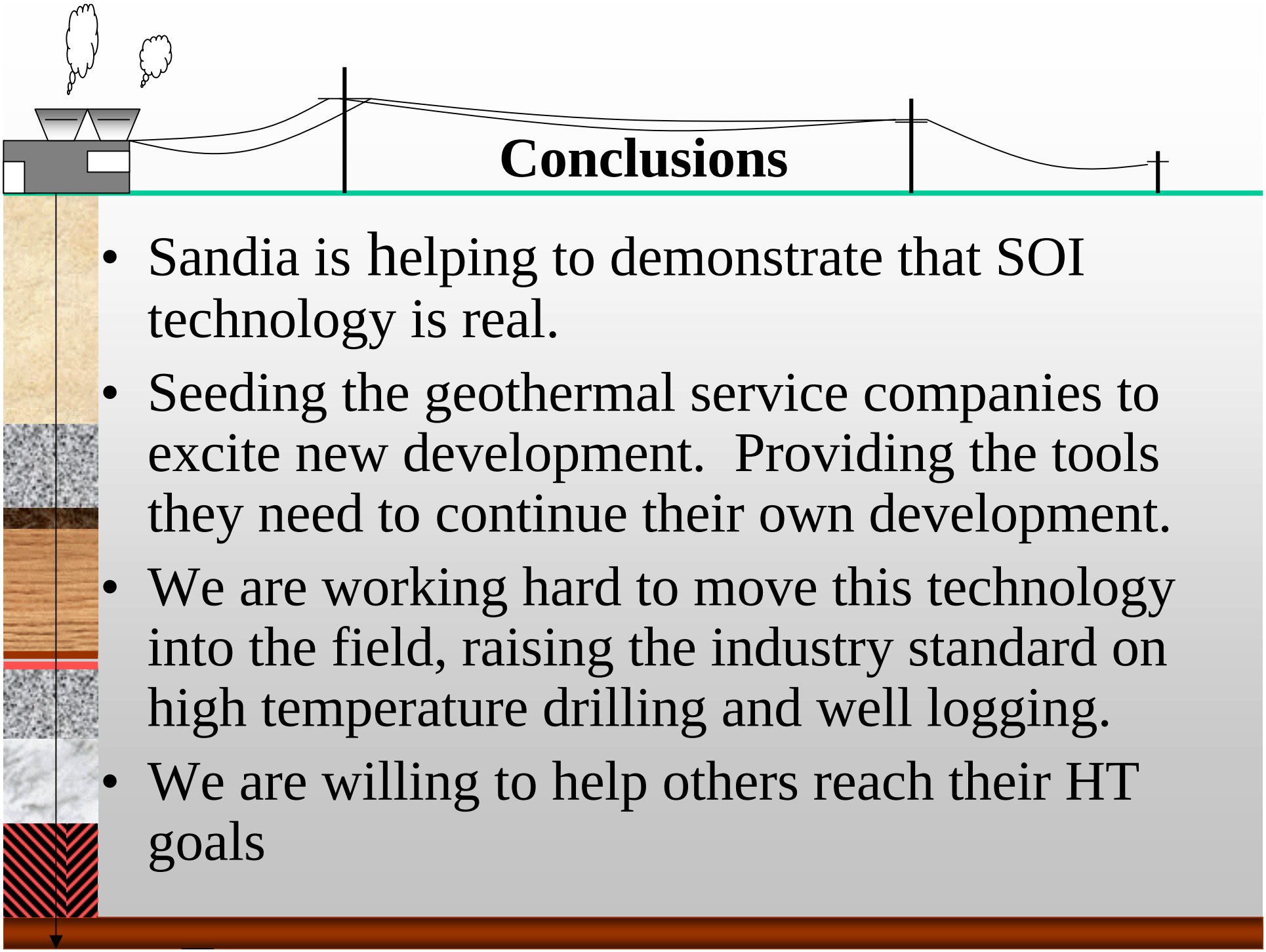
Education: Fabrication



- **180C and above basics**
  - Clean everything
    - We normally soak all mechanical housings at 250-300C for 48 hours to burn out machine oils
    - Remove all water or water vapor. We evacuate the assembled tool for 24 hours at 200-250C then back fill with Ar.
  - Polyimide printed wiring boards ok to 240C are improved by having no traces on the exposed layers
  - No good solders. We use high lead solder and water soluble flux. Must take care in cleaning the flux.
  - Preheat electronic components during assembly
  - Use only metal to metal seals
- **250C and above (limited experience)**
  - We laser weld connections where possible
  - We machine ceramic to form mounting fixtures using Beryllium-Nickel sockets

Education: Reports

- Battery report just released
- HT2L High-Temperature Long-Life Standard
  - Draft is out
- Azimuth measurement at 250C, report presently being written
- Capacitor challenge being set up should result in a report in Sept, 2003
- Fabrication procedures continue to be developed, report in March 2004
- Long-term demonstration report in June 2004



Conclusions

- Sandia is helping to demonstrate that SOI technology is real.
- Seeding the geothermal service companies to excite new development. Providing the tools they need to continue their own development.
- We are working hard to move this technology into the field, raising the industry standard on high temperature drilling and well logging.
- We are willing to help others reach their HT goals